ALLEN GROUP
Timely Flashes Bulletin
BULLETIN NO. 112
SERVICE DATA FROM THE NATION'S LEADING PRODUCER OF AUTOMOTIVE TEST EQUIPMENT

USING AN INFRARED EXHAUST GAS ANALYZER AS A DIAGNOSTIC TOOL

The Infrared Exhaust Gas Analyzer is an extremely useful tool for checking the combustion efficiency of a gasoline engine. Ideally, the Infrared tool (used with a scope) is best used as an integral part of every tune-up to verify the engine's mechanical and electrical condition. Besides being a tune-up tool, the Infrared is a highly underrated and misunderstood diagnostic tool. As a technician, it's fundamentally important you have a thorough understanding of the combustion process and the gases involved. This will give you the ability to make accurate tune-up/diagnostic decisions quickly, reduce comebacks, and increase customer confidence.

Let's take a look at what happens during the combustion process. The engine takes in a calibrated amount of air and fuel. The best air/fuel ratio is 14.7:1; 14.7 pounds of air for every 1 pound of fuel. Chemically, a normal "burn" looks like this. (Remember air is composed of 21% oxygen, 78% nitrogen, and 1% other gases.)

$$\underset{\text{(Fuel)}}{HC} + \underset{\text{(Oxygen)}}{O_2} + \underset{\text{(Nitrogen)}}{N_2} \rightarrow \underset{\text{(Carbon Dioxide)}}{CO_2} + \underset{\text{(Water)}}{H_2O} + \underset{\text{(Nitrogen)}}{N_2}$$

A bad "burn" can look something like this:

$$\underset{\text{(Fuel)}}{HC} + \underset{\text{(Oxygen)}}{O_2} + \underset{\text{(Nitrogen)}}{N_2} \rightarrow \underset{\text{(Unburned Fuel)}}{HC} + \underset{\text{(Carbon Monoxide)}}{CO} + \underset{\text{(Carbon Dioxide)}}{CO_2} + \underset{\text{(Oxides of Nitrogen)}}{NO_X} + \underset{\text{(Water)}}{H_2O}$$

A bad "burn" can be caused by incorrect fuel and/or air metering, defective/ misadjusted ignition components, mechanical engine problems, or defective emission control devices. In each case, these problems have a direct affect on the gases the Analyzer measures, namely Hydrocarbons (HC), Carbon Monoxide (CO), and Oxygen (O_2).

WHAT IS CO?
(MEASURED IN % BY VOLUME)

Carbon monoxide is formed by the partial burning of the fuel mixture in the combustion chamber due to a lack of oxygen.

There are various methods of creating oxygen starvation within the combustion chamber. One way is to provide a rich fuel mixture. In this way, for the same volume of intake to the combustion chamber, more fuel means less of something else. That something else will be less oxygen. Also with more fuel, more oxygen is required to convert the hydrocarbon to harmless carbon dioxide and water.

Another way of creating oxygen starvation is to restrict the air intake. Conditions like dirty air cleaners, clogged carburetor airbleeds, incrustation around the valve stem, etc., reduce the volume of air intake to the combustion chamber.

Improper carburetion is the major cause of higher than normal CO readings.

However, in order for the carburetor to function as designed, air intake must be unrestricted; exhaust, intake and PCV valves must be operational. Engine temperatures and manifold vacuum must be correct. What is seen coming from the tailpipe of the vehicle in the form of carbon monoxide is wasted energy and is detrimental to the environment.

WHAT IS HC?
(MEASURED IN PARTS PER MILLION; PPM)

Hydrocarbon is unburned fuel leaving the combustion chamber.

Any misfire, regardless of the cause will contribute to higher than normal HC readings.

The absence of a spark, the spark occurring at the wrong time, low compressions, insufficient spark duration and improper air fuel mixtures (especially extremely lean mixtures) produce hydrocarbon content.

Since this is unburned fuel in the tailpipe, an obvious waste of energy is shown in an inefficient combustion process.

Although hydrocarbon emissions from automobiles are not the major contributor to air pollution that carbon monoxide is, they are an important constituent of photochemical SMOG.

WHAT IS O_2? (MEASURED IN % BY VOLUME)

Oxygen is a necessary ingredient for all combustion. There must be enough O_2 present during combustion to convert the Hydrogen & Carbon (HC) into CO_2 and H_2O. If the AFR is too lean (not enough Carbon), O_2 will ve high. If the AFR is too rich, O_2 will be very low and CO will be high.

There are a number of reasons for the O_2 readings to be high that may or may not be engine related. High O_2 readings may be caused by any of the following:

- Air Pump not disabled properly and still supplying additional air to the converter.
- Gulp Valve or Pulse Air System not disabled properly and still supplying air to the converter.
- A leak in the exhaust system.
- An intake leak into the manifold causing excessive leanness creating engine misfires.
- A fouled plug or shorted plug wire causing complete misfire in one or more cylinders.
- Analyzer exhaust probe not inserted far enough into the tailpipe, which draws in extra air.
- A leak in the analyzer exhaust probe.
- A leak through the analyzer filter, not sealed properly, etc.

Catalytic converters mask HC/CO readings at the tailpipe, so O_2 is valuable in diagnosing both mixture and electrical/mechanical malfunctions.

To summarize, CO relates to fuel mixture, HC relates to engine misfires and O_2 is extremely valuable in verifying combustion efficiency and air/fuel ratio.

CARBURETOR IDLE MIXTURE ADJUSTMENT (NON-CATALYST ENGINES OR WITH EXHAUST PROBE INSTALLED AHEAD OF CONVERTER)

- Disable Air Pump/Pulse Air.
- Remove PCV valve from the valve cover.
- Disconnect canister purge hose.
- Lightly bottom both idle mixture screws and back them out 2 full turns.
- Start engine, bring to operating temperature and observe CO, HC, and O_2 Meters. They should be stable at this time.
- Adjust curb idle speed according to manufacturer's procedure and specifications on the underhood emissions label.
- Turn idle mixture screws in (lean) equally, 1/8 turn at a time, and wait for meters to reflect change.
- Continue to lean the mixture until HC and O_2 start to increase (lean misfire).
- Back out idle mixture screws (richen), 1/8 turn at a time, until HC and O_2 are stable.
- Reset idle speed as required and recheck idle mixture adjustment. (HC should be stable and below 400 PPM. O_2 should be stable and between .1 and 2.0%.)
- Reconnect PCV valve, canister purge, and air injection system.

This procedure can be used on engines equipped with catalytic converters; however, the "LEAN DROP IDLE" or "PROPANE ENRICHMENT" procedures are recommended for Non-Computer Controlled fuel systems. Refer to manufacturer's service manual for specific procedures.

HYDROCARBON PER CYLINDER

Engine performance is directly related to how well the engine breathes and what the engine breathes.

For diagnostic purposes we can measure the breathing characteristics of each cylinder by not allowing the mixture to burn in that cylinder.

The method of "Killing" the cylinder is accomplished by the use of the scope analyzer and selecting the individual cylinders one at a time.

PROCEDURE:

- Set the engine speed at approximately 1500 RPM.
- Disable Air Pump/Pulse Air Systems.
- Depress the cylinder KILL pushbutton and the desired cylinder pushbutton to prevent the fuel in that combustion chamber from burning.
- Artificially enrich converter cars to 3% CO for test.

The fuel that was not burned during the "Kill" will be emitted at the tailpipe.

What the engine requires is the INTAKE of fuel, COMPRESSION of fuel, TIMED IGNITION, and COMBUSTION of the fuel. If any of these are missing or wrong, engine performance will suffer.

The following chart shows some possible test results and probable causes.

1. Every other cylinder reads higher than the average.	Unbalanced carburetor, carburetor base or manifold air leak.
2. Two cylinders on the same intake runner. (In-Line 6 Cyl.)	Vacuum leak, check for hoses off, intake manifold leak.
3. One or two cylinders low.	Sticky or poorly seated valve, bad camshaft, intake manifold restriction . . . intake manifold restriction will likely be true at higher RPM as well, while a sticky valve may show more normal HC at high RPM.
4. All cylinders reading equal but cylinder balance reading low on some cylinders.	Not related to fuel, check scope for ignition if OK, check compression.

CATALYTIC CONVERTERS

Individual or multiple cylinder "Kill" testing while measuring the hydrocarbon output is an acceptable procedure. The specific cylinder should not be "Killed" for more than 10 seconds at one time and allow 30 seconds between cylinder "Kills" to allow the converter to restore its full operating capacity.

A slight increase in hydrocarbon content should be expected with each cylinder that is "Killed" (approximately 400-800 PPM).

EXHAUST ANALYSIS – IDLE AND CRUISE

Since Catalytic Converters mask HC and CO, a better gas analysis can be achieved by following this procedure.

- Start engine and bring to operating temperature.
- Stop engine and wait 10 minutes (allows converter to cool).
- Disable air injection system if so equipped. (If gas readings are being taken at the tailpipe, be prepared to record all readings within 2 minutes of engine restart. These gas readings will be more realistic since the converter won't normally relight within 2 minutes.)
- Restart engine and take HC, CO, and O_2 readings at idle and 2500 RPMs.
- Compare to the chart on the next page.

SOME TIPS TO KEEP IN MIND

1. A 5-10% variance in any chart value is acceptable.
2. A catalatic converter that is not active may give gas readings like a non-converter engine.
3. Any HC reading 1000 PPM or above indicates a bad misfiring problem.
4. Unstable CO readings indicate fuel delivery problems.
5. Bad fuel distribution normally causes higher unstable HC, O_2 readings and normal to high CO readings.
6. Unstable HC and O_2 readings usually indicate intermittent secondary problems.
7. Low speed air leaks become less significant at higher RPMs.
8. If the O_2 reading is 2% or greater, artificially enrich the engine while watching the "Carb Adjust" Meter. A 10% or more speedup means excessive leanness.

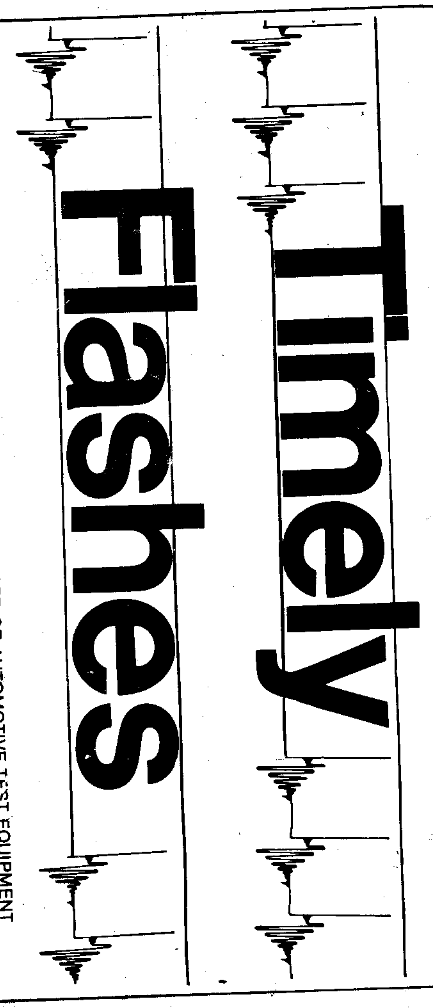
ALLEN INSTITUTE TRAINING PROGRAMS

Allen Testproducts currently offers programs for technicians to upgrade their knowledge and stay current with today's changing technology.

These programs are designed for the apprentice mechanic as well as the accomplished technician.

- **Allen Diagnostic Training Program - 32 Hours**
  Covers the operation and diagnosis of:
    - Cranking Systems
    - Charging Systems
    - Primary Ignition Systems
    - Secondary Ignition Systems
    - Emission Controls
    - Carburetion and Fuel Injection Systems
    - Infrared Exhaust Gas Analysis
- **GM Computer Command Control (CCC) -16 Hours**
  Covers the operation and diagnosis of:
    - CCC System Components
    - Air Management Systems
    - Electronic Spark Timing (EST)
    - Idle Speed Controls
    - Torque Converter Clutch (TCC)
    - Related Emission Controls
    - Carburetor Adjustments
    - CCC System Diagnostic Procedures
- **Emission Control Systems (California Only)**
  Covers the administration of the California Smog Inspection Program plus the operation and diagnosis of all emission control systems.

For further details, contact your local Allen Sales Representative.



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BULLETIN NO. 112

ALLEN GROUP
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INFRARED EXHAUST GAS ANALYSIS PARAMETERS FOR HC, CO, O_2

	IDLE		1500 RPM		2500 RPM		CONDITION/POSSIBLE CAUSE
	Converter	Non-Converter	Converter	Non-Converter	Converter	Non-Converter	
HC (PPM) CO (%) O_2 (%)	0 - 150 .1 - 1.5 .1 - 2.0	75 - 250 .5 - 3.0 .1 - 2.0	0 - 135 0 - 1.1 .1 - 2.0	50 - 200 .5 - 2.0 .1 - 2.0	0 - 75 0 - .8 .1 - 1.25	25 - 150 .1 - 1.5 (4 CYL. - 3%) .1 - 2.0	NORMAL GAS READING – STABLE VALUES
HC (PPM) CO (%) O_2 (%)	0 - 150 Above 3.0 0 - .5	75 - 250 Above 4.0 0 - .5	0 - 135 Above 3.0 0 - .5	50 - 200 Above 3.5 0 - .5	0 - 75 Above 3.0 0 - .5	0 - 100 Above 3.0 0 - .5	RICH MIXTURE: Idle mixture too rich; choke set too rich or not opening fully; power valve leaking; float level too high; restricted air cleaner; PCV restricted; contaminated crankcase.
HC (PPM) CO (%) O_2 (%)	0 - 150 0 - 1.0 1.5 - 3.0	75 - 250 0 - 1.0 1.5 - 3.0	0 - 135 0 - .8 1.0 - 2.5	50 - 200 0 - .9 1.0 - 2.5	0 - 75 0 - .25 1.0 - 2.0	0 - 100 0 - .75 1.0 - 2.0	LEAN MIXTURE: Low float level; idle mixture lean; cruise mixture lean; small air leaks; cracked or pulled loose vacuum lines.
HC (PPM) CO (%) O_2 (%)	50 - 850 0 - .3 4 - 9	400 - 1200 0 - .75 4 - 9	50 - 850 0 - .3 4 - 9	400 - 1200 0 - .75 4 - 9	50 - 750 0 - .3 2 - 7	400 - 1200 0 - .75 2 - 7	LEAN MISFIRE: Severe air leak; bad spark plug or wire; stuck PCV; mis-adjusted/defective carb.
HC (PPM) CO (%) O_2 (%)	50 - 850 .1 - 1.5 4 - 12	800 - PEG .5 - 3.0 5 - 12	50 - 850 0 - 1.1 4 - 12	800 - PEG .5 - 2.0 5 - 12	50 - 750 0 - .8 4 - 12	800 - PEG .1 - 1.5 5 - 12	MISFIRE: Overadvanced timing; fouled plug; open/grounded plug wire; EGR stuck open.